

# Extreme Access & Lunar Ice Mining in Permanently Shadowed Craters

Completed Technology Project (2012 - 2013)



## Project Introduction

Results from the recent NASA Lunar CRater Observation and Sensing Satellite, or LCROSS, mission in 2010, indicate that water (H<sub>2</sub>O), ice and other useful volatiles such as Carbon Monoxide (CO), and Helium (He) are present in the permanently shadowed craters at the poles of the moon. However, the extreme topography and steep slopes of the crater walls make access a significant challenge. In addition temperatures have been measured at 40K (-233 C) so quick access and exit is desirable before the mining robot cold soaks. The Global Exploration Roadmap lists extreme access as a necessary technology for Lunar Exploration.

During the last 10 years, missions to the moon have revealed locations where ice water could be located beneath the surface. The moon is not flat, but has permanently shadowed craters at the north and south poles that hold ice water and volatiles. The Shackleton crater at the south pole of the Moon is a very compelling target. Researchers think that up to 22 percent of the surface content could be water ice.

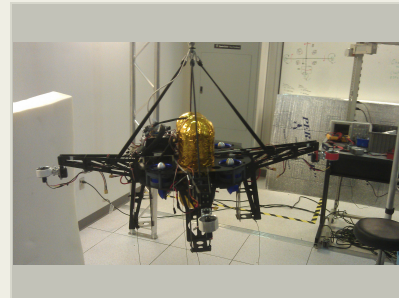
Extreme access will be required on these missions into the permanently shadowed regions of the moon. There are hundreds of small craters at the moon's North Pole, and there is data that shows they might contain up to 600 million metric tons of water ice. Space mining requires access, resource excavation, extraction, and then some level of processing.

## Anticipated Benefits

Lightweight Composite material (Carbon Fiber hybrid) structures and parts  
Micro-Excavator with zero-net reaction force for mining Cold gas rocket propulsion system concept design with re-charging capability from mined volatiles at the "mother ship" lander Integrated bread board test in the Granular Mechanics and Regolith Operations, or GMRO, lab regolith testbed.

This project could benefit NASA in solving the extreme access problem with a new device that is a flying micro-mining robot.

This proposal meets the objectives of the Technology Area TA02 In Space Propulsion Technologies, TA 04 Robotics, Tele Robotics and Autonomous Systems, Technology Area 07, Human Exploration Destination Systems and TA 14 Thermal Management Systems Roadmaps. It is in direct alignment with the Kennedy Space Center technology capability area of In-Situ Resource Utilization (ISRU) and Surface Systems and strategically important as a future line of business for KSC.



Extreme Access prototype during tethered flight testing. In later phases, the vehicle's electric ducted fans will be replaced with cold-gas thrusters.

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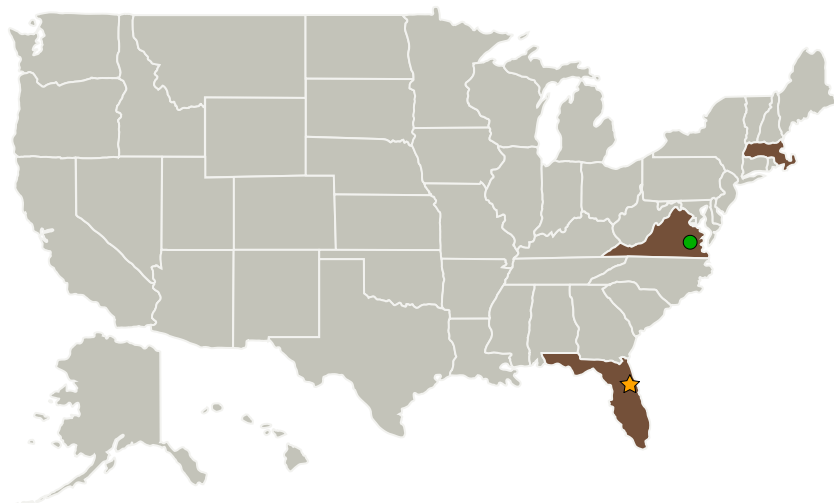
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## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Kennedy Space Center (KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
● Langley Research Center (LaRC)	Supporting Organization	NASA Center	Hampton, Virginia
QinetiQ North America (QNA)	Supporting Organization	Industry	

### Primary U.S. Work Locations

Florida	Massachusetts
Virginia	

## Organizational Responsibility

### Responsible Mission Directorate:

Mission Support Directorate (MSD)

### Lead Center / Facility:

Kennedy Space Center (KSC)

### Responsible Program:

Center Independent Research &amp; Development: KSC IRAD

## Project Management

### Program Manager:

Barbara L Brown

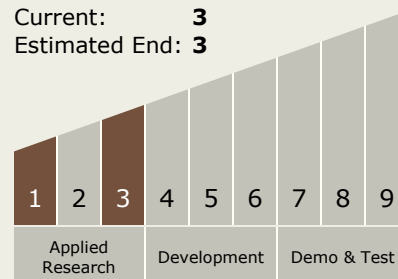
### Project Manager:

Nancy P Zeitlin

### Principal Investigator:

Robert P Mueller

## Technology Maturity (TRL)

Start: **1**Current: **3**Estimated End: **3**

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## Images



### Extreme Access prototype during tethered flight testing.

Extreme Access prototype during tethered flight testing. In later phases, the vehicle's electric ducted fans will be replaced with cold-gas thrusters.

(<https://techport.nasa.gov/image/2731>)

## Technology Areas

### Primary:

- TX07 Exploration Destination Systems
  - └ TX07.1 In-Situ Resource Utilization
    - └ TX07.1.2 Resource Acquisition, Isolation, and Preparation